CURRENT TRANSFORMER PERFORMANCE IN HIGH VOLTAGE AND LOW VOLTAGE SYSTEMS

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JUDUL: **CURRENT TRANSFORMER PERFORMANCE IN HIGH VOLTAGE AND LOW VOLTAGE SYSTEMS**

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A project report submitted in partial
fulfillment of the requirement for the award of the
Degree of Master of Electrical Engineering

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APRIL 2008

I declare that this report on "Current transformer performance in high voltage and low voltage systems" is the result of my own project except for works which have been cited in the references. The report has not been accepted any degree and not concurrently submitted in candidature of any other degree.

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Date : APRIL 2008

For my dearest wife Fazlinda,

My beloved sons Muhammad Khairul Afif

&

My family for their encouragement and blessing

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In the name of Allah S.W.T., the Most Beneficent, the Most Merciful. Foremost, all praise to Allah for the entire incredible gift endowed upon me and for giving me the health and strength to complete this final project.

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ABSTRACT

Current Transformers (CT's) are instrument transformers that are used to supply a reduced value of current to meters, protective relays, and other instruments. Current transformer provide isolation from the high voltage primary, permit grounding of the secondary for safety, and step-down the magnitude of the measured current to a value that can be safely handled by the instruments. It is one of the critical protective devices in a high voltage substation and low voltage switch board. It is used as a sensor to detect faults that will generate signal to trip the protective relay. The performance of current transformer is very important in preventive and predictive maintenance. It can reduce number of injury and minimize system and equipment failure as well as help to reduce the cost. In this work, the method of measuring and testing the electrical characteristics of CT's are first investigated and the experience gained in the measurement and testing are then used to check and verify the characteristics of CT's found the low voltage switchboard of the Electrical Installation lab. The procedures and steps involved in the measurement and testing are reported and discussed in this work. The method of measurement in the low voltage switchboard are also reported and discussed in this work.

ABSTRAK

Pengubah arus adalah pengubah peralatan di mana ia di gunakan untuk membekalkan nilai arus yang berkurangan kepada meter, geganti perlindungan dan peralatan – peralatan lain. Pengubah arus menyediakan pemencilan daripada voltan tinggi di bahagian utama yang membenarkan pembumian di bahagian sekunder untuk tujuan keselamatan dan magnitud arus yang di ukur di kurangkan kepada satu nilai yang lebih selamat di kawal oleh peralatan tersebut. Ia adalah salah satu peralatan perlindungan yang kritikal di pencawang voltan tinggi dan voltan rendah di papan suis. Ia di gunakan sebagai penderia untuk mengesan kerosakan di mana ia boleh menghasilkan isyarat untuk menghidupkan geganti perlindungan. Prestasi pengubah arus adalah sangat penting dalam penyelenggaraan pencegahan dan jangkaan.Ia boleh mengurangkan bilangan kemalangan, meminimumkan sistem dan kegagalan peralatan di samping mengurangkan kos.Dalam kerja ini, kaedah mengukur dan menguji ciri ciri elektrik bagi pengubah arus di siasat dan dari pengalaman yang di perolehi dalam mengukur dan menguji tersebut di gunakan untuk menyemak dan mengenalpasti ciri-ciri pengubah arus dalam voltan rendah di papan suis di dalam makmal pemasangan elektrik. Langkah langkah yang terlibat di dalam pengukuran dan pengujian di laporkan dan di bincangkan di dalam kerja ini.Kaedah pengukuran di dalam voltan rendah di papan suis juga di laporkan dan di bincangkan.

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LIST OF SYMBOLS/ ABBREVIATIONS

Symbols:

i_1	-	Primary current
i_2	-	Secondary current
n_1	-	Primary turns
n_2	-	Secondary turns
H	-	Magnetic field
i_e	-	Excitation current
n	-	Winding ratio
R_1	-	Resistance of the primary winding
R_2	-	Resistance of the secondary winding leakage inductances
l_1	-	Primary leakage inductances
l_2	-	Secondary leakage inductances
ϕ	-	Flux
e_1	-	Primary emf
e_2	-	Secondary emf,
v_1	-	Primary potential
v_2	-	Secondary potential
μ_r	-	Relative permeability
L	-	Inductor
Vs	-	Secondary voltage
f	-	Frequency
B	-	Magnetic flux density
A	-	Net core area
k_1	-	A unitary constant corresponding to the unit chosen for B and A

k_2	-	A constant depending on unit H and l
Ww	-	Watt per weight

Abbreviations:

CT	-	Current Transformer
DC	-	Direct Current
HV	-	High Voltage
LV	-	Low Voltage
VT	-	Voltage Transformer
PT	-	Potential Transformer
IDMT	-	Inverse Definite Minimum Time
ACB	-	Air Circuit Breaker
MCCB	-	Moulded Case circuit breaker
MCB	-	Miniature Circuit Breaker
IEC	-	International Electrotechnical Comission
IEEE	-	Electrical and Electronic Engineer
ANSI	-	American National Standards Institute
TC	-	Test Certificate
MK	-	Marshalling Kiosk
BBP	-	Bus Bar Protection

CHAPTER I

INTRODUCTION

1.1 Objective

i To measure the characteristics of different type of current transformer

ii To familiarize with the measuring equipment used to test current transformers.

iii To assess the different techniques of measuring the characteristic of current transformer.

iv To test current transformers in high voltage substations and low voltage switch boards.

1.2 Statement of Problem

i Insulation is the major component, which plays an important role in the life expectancy of the current transformer. To determine the performance and aging of the asset, insulation behavior is a main indicator. In the absence of insulation monitoring and assessment, good number of current transformer due to insulations problems, before reaching to their designed technical life. Insulation failure can cause electrical shocks, creating a real hazard to personal and equipment.

ii If the value of knee point voltage that is gain doesn't match with the name plate value, it will show that it has been cheated by the manufacture, low quality of the current transformer and the current transformer is damage.

iii The ratio of Current Transformer that does not follow the manufacturer's data will give a problem to the protection system. When there is a difference ratio value in the secondary current, it may give wrong information to the relay. Therefore the relay can't recognize the signal or sometimes the signal detected can't deliver right information. As the conclusion, the protection system does not work as expected

1.3 Project Scope

The project focuses on testing the high voltage substation and low voltage switch board.

These are the scope of the testing:-

1. DC Resistance of CT and Loop Resistance of Secondary Windings Test
2. Magnetization Test of CT Cores
3. Polarity Tests
4. Ratio Check (Primary Injection)
5. Insulation Test

This project will be done in the Makmal Pendawaian Domestik, Jabatan Kejuruteraan Elektrik Kuasa, Fakulti Kejuruteraan Elektrik dan Elektronik at Universiti Tun Hussein Onn Malaysia. Project will be focused on method for testing the current injection by using a secondary current injection test set (SCITS100).

These are the scope of the testing:-

1. Current transformer excitation characteristics test
2. Current transformer ratio tests
3. Polarity checks

1.4 Significance of the study

The purpose of this project is to:

1. Familiarize the performance and the characteristics of the current transformer.
2. To study the types of current transformer.
3. To gain a testing procedure of the current transformer
4. To explore a high voltage (HV) and low voltage (LV) system that is related closely with the industrial sector.

CHAPTER II

CURRENT TRANSFORMER

2.1 Introduction to Current Transformers

This chapter shows the purpose of current transformer. A current transformer is kind of electrical instrument that is produced particularly to provide a flow of current in the secondary circuit that is properly perpendicular to the amount of current flowing in its primary circuit. It actually measures alternating current flowing by way of a conductor. As it is used to measure current, a current transformer is normally classified as a kind of instrument transformer. It could also measure the voltage drop across any known resistor. This could be applied for a low current application but is often impractical for high current applications. The resistor consumes more power (decreasing efficiency) unless the resistor is extremely low in value, in such case there might be very little voltage the measure. The resistor can also be very large. The resistor's heat might affect the resistor value, so reducing accuracy of its measurement.

A current transformer could accurately calculate the alternating current and put out a reasonable voltage that is proportional to the current, but it is without as much heat and size that an appropriate resistor may require. The current transformer could perform its function with extremely little insertion loss into the conductor current is been calculated. A current transformer as well offers voltage isolation among the conductor and the measuring circuitry. Proper function of a current transformer wants use of a load resistor. And load resistor is normally referred as to a "burden resistor".

The most excellent core structure for a current transformer in way of electrical performance is a toroidal coil. Many toroidal current transformers normally have only one winding. This winding is generally a "high turns" winding that functions as the secondary winding. In application, the toroidal current transformer is fallen over an end of a high current wire or buss bar that further conducts the primary current.

Split core current transformers are especially planned so that they could be gathered around a buss bar without cutting off the buss bar. "C" cores and "U" core structures are normally used for split-core current transformers as they are comparatively simple to take apart and put back together across the buss bar. Traditionally, this has not been realistic for toroidal coils, but there are presently some supple toroids that allow the "split-core" feature of installing it around a buss bar. They have restricted application. Some printed circuit board applications would use bobbin wound current transformers with two or more windings.

2.2 Theoretical of Current Transformer

Current transformers consist of a magnetic circuit in toroid form. The primary is made up of n1 turns or simply a single conductor crossing the toroid ($n_1 = 1$). The secondary is wound in n_2 regular turns around this toroid. Ampere's theorem states that the sum of the ampere-turns is equal to the circulation of the magnetic field vector.

$$n_1 i_1 + n_2 i_2 = \int \vec{H}.\vec{n}.dl \tag{2.1}$$

where

$\vec{H}$ = magnetic field

$\vec{n}$ = tangent unit vector

A transformer is said to be perfect when

$$\int \vec{H}.\vec{n}.dl = 0 \tag{2.2}$$

In the real transformer, this term refers to the error introduced by the magnetic circuit and defines the exciting current i_e formed at the secondary by:

$$n_1 i_1 + n_2 i_2 = n_2 i_e \tag{2.3}$$

If $n = \frac{n_2}{n_1}$ is the winding ratio, the relationship is written as:

$$\frac{i_1}{n} + i_2 = i_e \tag{2.4}$$

The transformer can then be represented (figure 2.1) as having two parallel elements:

i. a perfect transformer of ratio n delivering a current i_1/n at the secondary,

ii. impedance which consumes a current i_e.

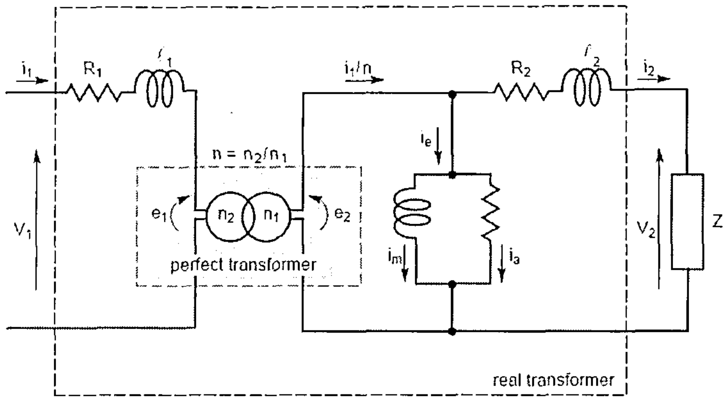


Figure 2.1 Current Transformer equivalent circuit

Moreover, each winding, both primary and secondary, creates a slight voltage drop due to the resistance of the winding (R_1 and R_2) and to the leakage inductances (l_1 and l_2). Since, in the case of the CT, the secondary winding is tight and regular, l_2 need not beconsidered. If ϕ is the flux common to both windings, the following can be written between the emf e_1, e_2 and the difference in potential v_1, v_2:

$$v_1 = e_1 + R_1 i_1 + l_1 \frac{di_1}{dt} \tag{2.5}$$

$$e_2 = v_2 + R_2 i_2 + l_2 \frac{di_2}{dt} \tag{2.6}$$

$$e_1 = n_1 \frac{d\phi}{dt} \tag{2.7}$$

$$e_2 = n_2 \frac{d\phi}{dt} \tag{2.8}$$

If all the functions described are sinusoidal of pulsation w, the following can be written vectorially:

$$\vec{V}_1 = \vec{E}_1 + (R_1 + jl_1\omega)\vec{I}_1 \tag{2.9}$$

$$\vec{E}_2 = \vec{V}_2 + R_2\vec{I}_2 \tag{2.10}$$

$$\vec{E}_1 = jn_1\omega\vec{\Phi}\vec{E}_2 = -jn_2\omega\vec{\Phi} \tag{2.11}$$

$$\frac{\vec{I}_1}{n} + \vec{I}_2 = \vec{I}_e \tag{2.12}$$

The wiring diagram in figure 1 result in the vectorial representation in figure 2.2.

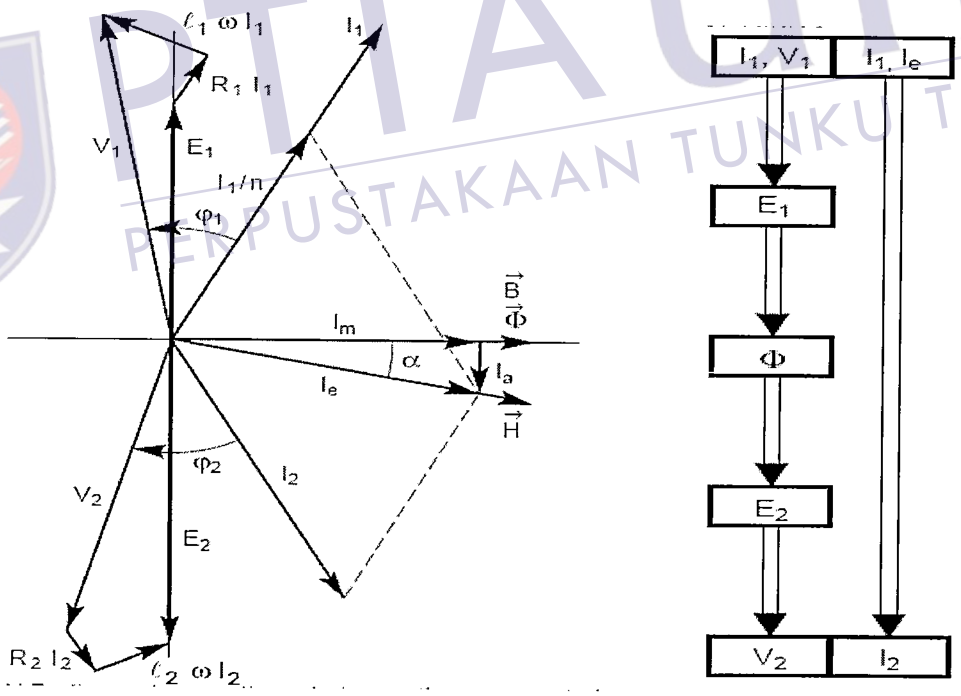


Figure 2.2 Current transformer phasor diagram

The exciting current $\vec{I}_e$ is broken down on the axes $\vec{\Phi}$ and $\vec{E}$ into:

$$\vec{I}_e = \vec{I}_a + \vec{I}_m \tag{2.13}$$

where $\vec{I}_a$ represents the part of this current lost in the magnetic circuit (iron losses due to hysteresis and eddy currents) and $\vec{I}_m$ is the magnetising current which transfers power from one winding to the other by creation of a magnetomotive force which induces the flux $\vec{\Phi}$

2.2.1 Hysteresis - Saturation

Magnetic circuit quality is defined by the relationship it imposes between the induction vector B and the magnetic field vector H. At a given moment and in a fixed point, these two vectors are linked by the relative permeability of the magnetic material μ_r such that:

$$\vec{B} = \mu_o \mu_r \vec{H} \tag{2.14}$$

A magnetic circuit is thus characterized by the curve b = f (h) known as the magnetising curve. According to the different material types, the curves in figure 2.3 are obtained, the results of sinusoidal excitation (primary current). In sinusoidal state, b represents voltage since:

$$\vec{B} = \frac{\Phi}{S} \vec{n} \tag{2.15}$$

$$\vec{E}_2 = n_2 j\omega\vec{\Phi} \tag{2.16}$$

$$\vec{V} = \vec{E}_2 \tag{2.17}$$

h represents the exciting current since

$$n_2 i_e = \int \vec{H}.\vec{n}.dl \tag{2.18}$$

assuming that

$$\vec{H}.\vec{n} = H = \text{constant} \tag{2.19}$$

$$n_2 i_e = L.H \tag{2.20}$$

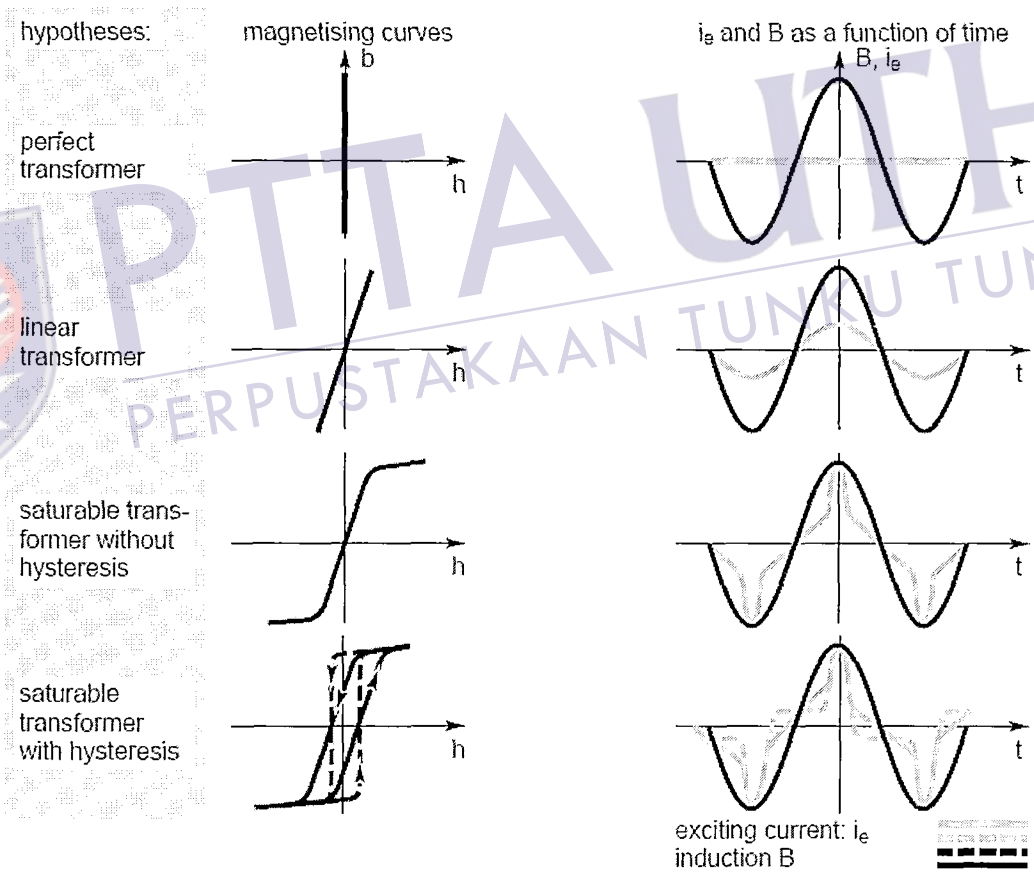


Figure 2.3 Magetising curve and their incidence on i_e

2.2.2 Perfect transformer

Permeability of the medium is assumed infinite

$$\vec{H} = 0 \text{ hence } I_e = 0 \text{ and } \vec{I}_2 = \frac{\vec{I}_1}{n} \qquad (2.21)$$

This hypothesis approaches the real situation with CTs since they normally work far below saturation. I_2 is then the mirror image of I_1.

2.2.3 Linear transformer

Permeability of the medium is constant

$$B = \text{Cste} \times H \qquad (2.22)$$

hence i_e and i_2 are sinusoidal functions.

2.2.4 Saturable transformer without hysteresis

Saturation is the sudden variation of μ_r from a high value to a low value at the point known as the «saturation bend».Induction b then increases only slowly and i_e ie deforms to form a peak.

2.2.5 Saturable transformer with hysteresis

The magnetising curve is undoubled, thus indicating the resistance of the magnetic circuit to the induction variations. Curve i_e then exhibits a characteristic «swing». The magnetising curve of a CT can easily be observed using an oscilloscope

2.3 Type of current transformer testing

2.3.1 Insulation Test

Insulation test by using 1 kV insulation test unit are actually to ensure the CT windings and the secondary circuit (cabling) is highly isolated from the ground. The high insulation is very important to prevent the current path circulate through the earth since the star point of the CT is grounded.

2.3.2 Magnetization Test of CT Cores

The objective of the test is to define the Knee point of the each CT cores. The knee point is defined as 10% of current increasing will result 50% of voltage variation

2.3.3 Polarity Tests

The test is performed to ensure all the CT cores facing to the correct direction for the protection and metering purpose.

2.3.4 DC Resistance of CT Cores and Loop Resistance

The test is performed to ensure the secondary circuit has got its continuity and the circuit burden can be measured and compared with the CT burden. The maximum circuit burden is expressed as, S_{max} = Rated VA/I_n^2.

2.3.5 Ratio Tests

The test is performed to ensure the ratio of all CT cores is accordingly with the CT specification details.

CHAPTER III

HIGH VOLTAGE AND LOW VOLTAGE PROTECTION SYSTEM

3.1 Substation protection

Substations serve as sources of an energy supply for the local areas of distribution in which they are located. Their main functions are to receive energy transmitted at high voltage from the generating stations, reduce the voltage to a value appropriate for local use, and to provide facilities for switching (Fig.3.1).

Substations have some additional functions. They provide points where safety devices may be installed to disconnect circuits or equipment in the event of trouble. Voltage on the outgoing distribution feeders can be regulated at a substation. In addition, a substation is a convenient place to make measurements to check the operation of various parts of the system.

Some substations are simply switching stations where different connections can be made between various transmission lines.

Some substations are entirely enclosed in buildings, while others are built entirely in the open (Fig. 3.2). In this latter type, the equipment is usually enclosed by a fence. Other substations have step-down transformers, high voltage switches, vacuum circuit breakers and lightning arresters located just outside the substation building within which are located the relaying and metering facilities.

3.2 Factors Influencing Location

Sites for substations are generally selected so that the stations will be as near as possible to the load center of the areas which they are intended to serve. Availability of land, cost, local zoning laws, future load growth, and taxes are just a few of the many factors which must be considered before a site is ultimately chosen.

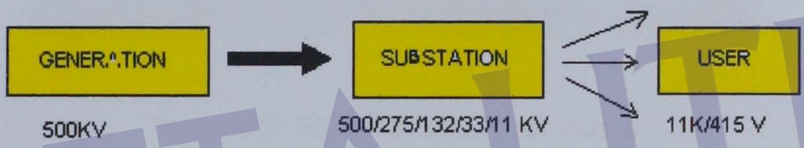


Figure 3.1: some function of substation

3.3 Typical Features of a Substation

Substations usually have two or more incoming supply transmission lines for reliability. Many of these stations are operated automatically, with control circuitry back to an operating center. Such centers not only tell the operators the condition of the stations, but enable them to operate circuit breakers and other equipment remotely. These control circuits may be privately owned wires, public telephone circuits, or microwave installations. The substation often also serves as a convenient place where an overhead portion of a transmission line is connected to an underground portion.

The design of the substation arrangement should be such as to permit taking out of service several lines or unit for operating or maintenance purpose without effacting the continuity of service.

Figure 3.2: 500/275/132 KV substation

3.4 Substation Equipment

3.4.1 The Power Transformer

The voltage of the incoming supply is changed to that of the outgoing sub transmission or distribution feeders by means of a transformer.Fundamentally, a power transformer consists of two or more windings placed on a common iron core. All power transformers have a primary winding and one or more secondary windings. The core of a power transformer is made of laminated iron and links the coils of insulated wire that are wound around it. There is no electrical connection between the primary and the secondary; the coupling between them is through magnetic fields. This is why power transformers are sometimes used for no other purpose than to isolate one circuit from another electrically. When this is done, the transformer used for this purpose is called an "isolating" transformer.

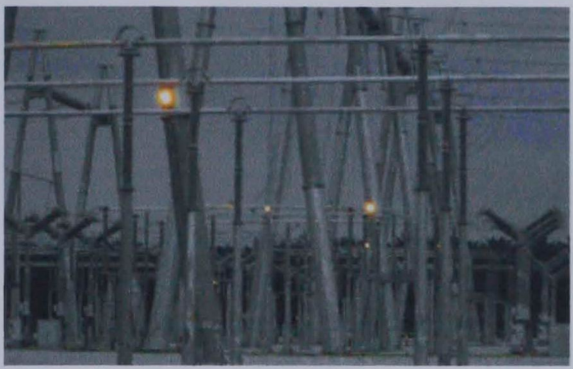
The winding that is connected to the source of power is called the primary, and the winding connected to the load is called the secondary. The essential function of the conventional power transformer is to transfer power from the primary to the secondary with a minimum of losses. As we shall see, in the process of transferring energy from primary to secondary, the voltage delivered to the load may be made higher or lower than the primary voltage.

Figure 3.3: Power Transformer

3.4.2 Bus Bars

Bus bar is a term used for a main bar or conductor carrying an electric current to which many connections may be made. Buses are merely convenient means of connecting switches and other equipment into various arrangements. The usual arrangement of connections in most substations permits working on almost any piece of equipment without interruption to incoming or outgoing feeders.

Some of the arrangements provide two buses to which the incoming or outgoing feeders and the principal equipment may be connected. One bus is usually called the "main" bus and the other "auxiliary" or "transfer" bus. The main bus may have a more elaborate system of instruments, relays, etc., associated with it. The switches that permit feeders or equipment to be connected to one bus or the other are usually called "selector" or "transfer" switches.



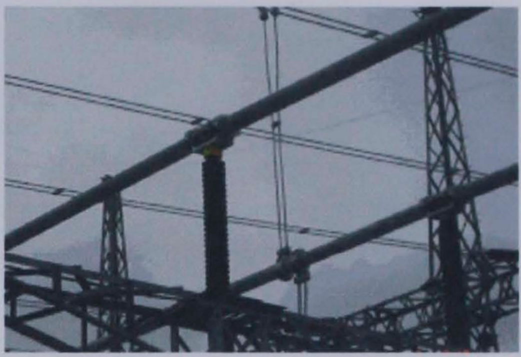
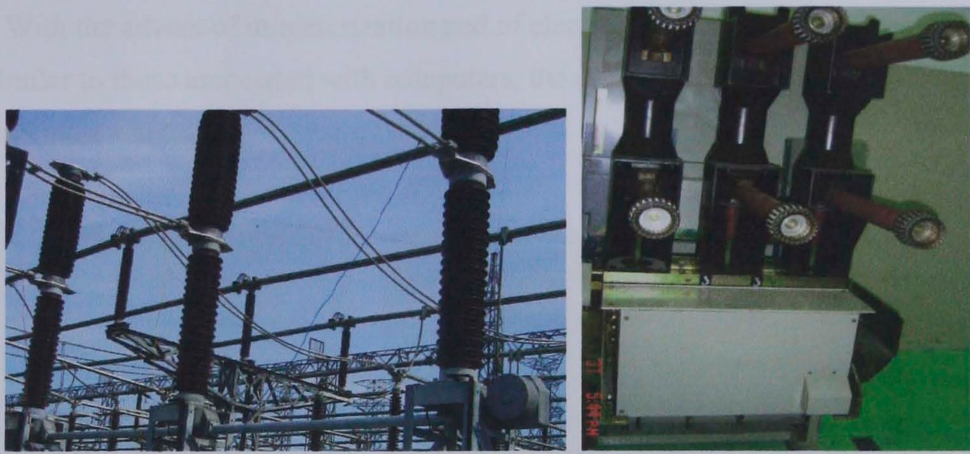


Figure 3.4: Busbar

3.4.3 Circuit Breakers

Circuit breakers are used to interrupt circuits while current is flowing through them. The making and breaking of contacts is done under vacuum. As explained previously, the vacuum serves to quench the arc when the circuit is opened. The operation of the breaker is very rapid when opening. As with the transformer, the high-voltage connections are made through bushings. Circuit breakers of this type are usually arranged for remote electrical control from a suitably located switchboard.



(a) 132KV (b) 33KV

Figure 3.5: Circuit Breaker

3.4.4 A protective Relays

A relay is a low-powered device used to activate a high-powered device. In a transmission or distribution system, it is the job of relays to give the tripping commands to the right circuit breakers.

The protection of the lines and equipment is of paramount importance and is usually accomplished by the opening of circuit breakers automatically actuated by relays. In general, it is more important to provide protection for the components of a transmission system than on a distribution system. Greater blocks of load may be affected and resultant damage to lines and equipment may be more costly. Relays are used to protect the feeders and the equipment from damage in the event of fault. In effect, these relays are measuring instruments, but equipped with auxiliary contacts which operate when the quantities flowing through them exceed or go below some predetermined value. When these contacts operate, they in turn actuate mechanisms which usually operate switches or circuit breakers, or in the case of the regulator, operate the motor to restore voltage to the desired level.

With the advent of miniaturization and of electronic gadgetry, including silicon chips similar to those associated with computers, the operation of such relays has become faster and more reliable.

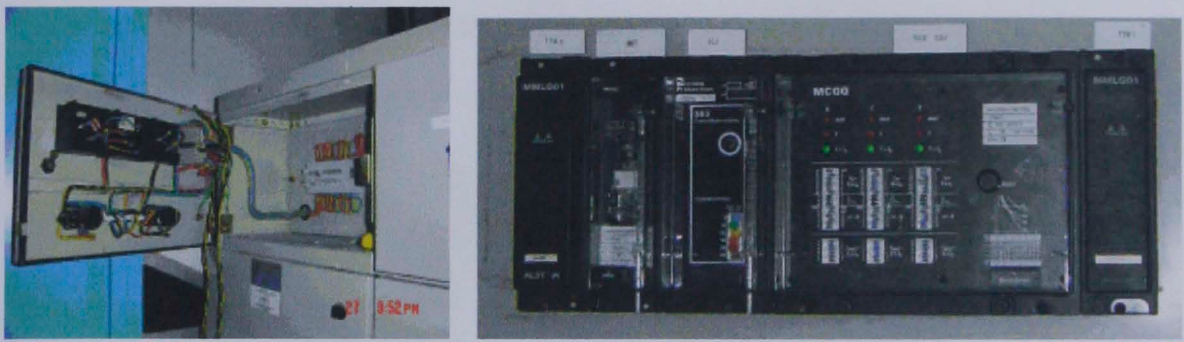


Figure 3.6: Over current Relay

3.4.5 High Voltage Disconnect Switches (Isolator)

Switches used to visibly isolate parts of a substation during maintenance or repair periods. They can also be used to reconfigure connections between sub transmission lines and/or power transformers. Disconnect switches are classified as either load break or no-load break. Load break switches can open and close with normal load current flowing through them. No-load break switches can only open and close if there is no current. Disconnect switches are not able to interrupt fault currents.

Figure 3.7: Isolator

3.4.6 Voltage and Current Transformers

These devices step down high voltages and currents to levels usable by meters and relays. Voltage transformers and current transformers arc commonly referred to as VTs and CTs, respectively. Voltage transformers are sometimes referred to as potential transformers (PTs).

Figure 3.8 (a): Current Transformer

Figure 3.8 (b): Voltage Transformer

3.4.7 Circuit Switchers

Combination devices consisting of a visible disconnect switch and circuit breaker. They typically do not have a high short circuit interruption rating, but save space and cost less than purchasing a switch and breaker separately. Circuit switchers are typically used in rural areas or other parts of the system where available fault current is low.

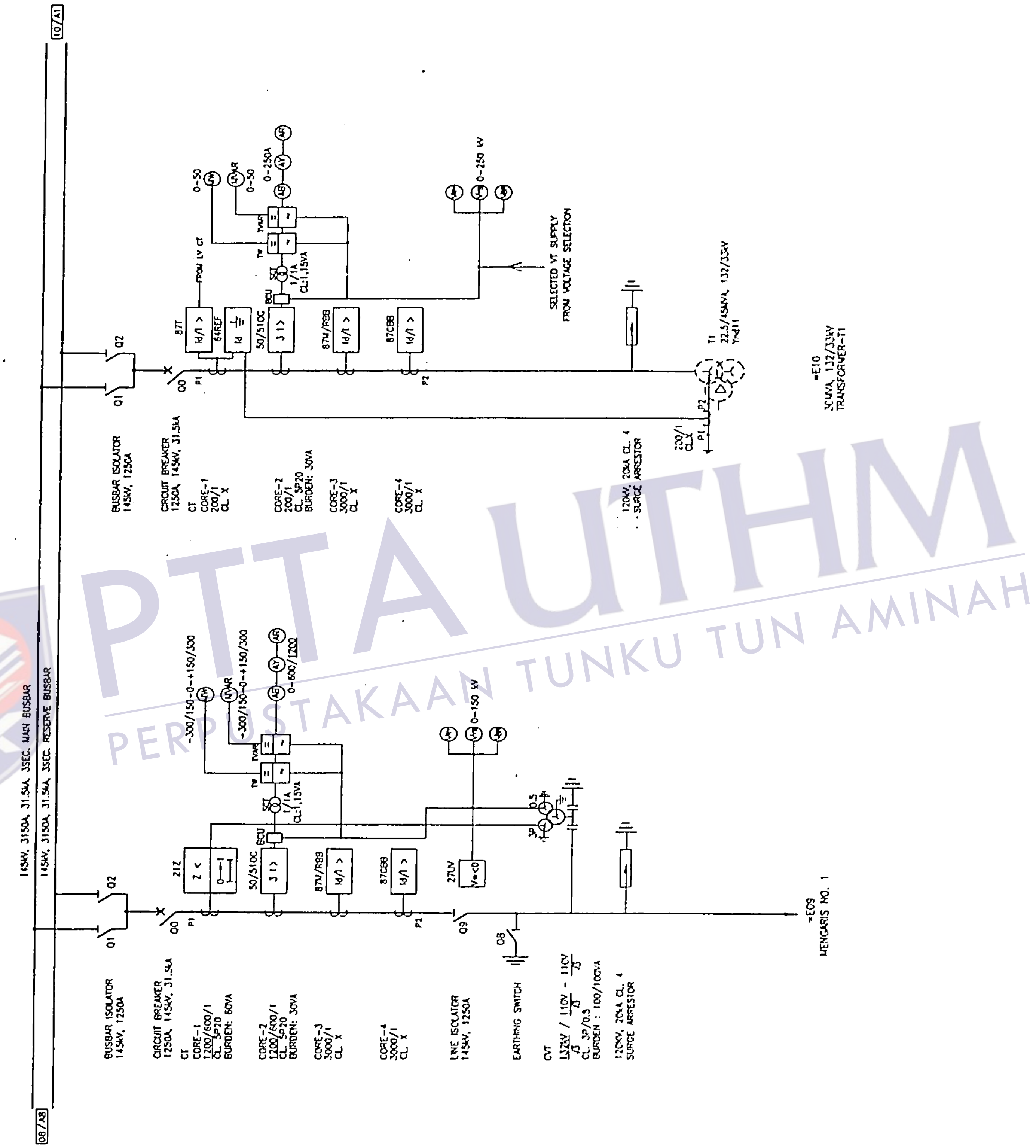


Figure 3.9: Single line diagram for 132KV system substation

3.5 Low Voltage Switch Board Protection

3.5.1 Introduction

In the low voltage system, the short circuit and other abnormal conditions often occur. The heavy current associated with short circuit is likely to cause damage to equipment if suitable protective devices are not provided for the protection of each section of the switch board. Abnormal condition is called as fault. One way or solution when a fault occurs in an element in low voltage system, a protective devices are needed to isolate the fault element as quickly as possible to keep healthy section of the system in normal operation. The fault must be cleared within a fraction of a second. If a fault persists on the system for a longer period, it may cause damage to some important sections of the system. Therefore the protective devices are very importance to ensure the big damages are not occurring.

In the low voltage system, the main focus is to the current transformer, protective relay and circuit breaker. A protective devices does not anticipate or prevent the occurrence of a fault, rather it takes action only after a fault has occurred. This is to ensure that fault will not give a major damage to the system.

3.5.2 Flow chart of Low Voltage Main Switch Board

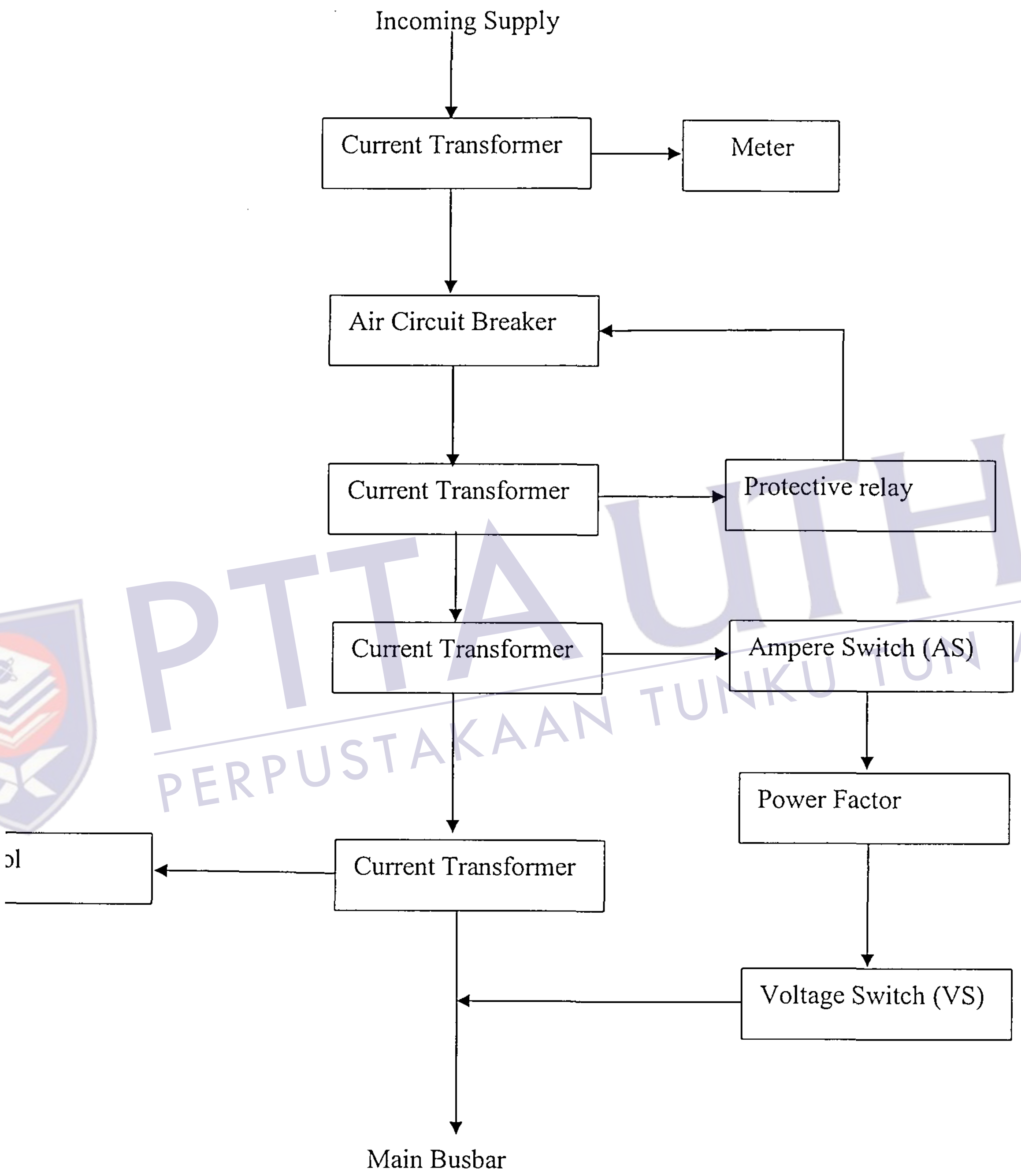


Figure 3.10 : Flow chart of Low Voltage Main Switch Board

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